Culture of Centrarchids

Stephen A. Flickinger and Julien Holt Williamson

The family Centrarchidae contains the most popular warmwater sport fishes in the U.S. The black basses, assorted sunfishes, and both crappie species account for a very large portion of angling harvest. Because of strong fisherman interest, there is need to propagate various centrarchid species for introductory stockings, corrective stockings, and in some waters maintenance stockings. In general, satisfactory culture techniques have been worked out for these species but many hatchery workers hope for improvements in the future. Perhaps some readers have already made advancements and others of you will use the background information presented in this chapter to solve problems in a new way. Please share your techniques in revisions of this chapter so that culture of centrarchids can be on a par with culture of trout and catfish.

BLACK BASS

The three species that have been propagated in hatcheries are largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieuii*), and spotted bass (*M. punctulatus*). The three species respond to the same basic techniques, and therefore unless an exception is specifically mentioned, what we say about one species should be considered true for the other species.

Brood Stock

Typically, brood bass are domesticated fish that have demonstrated reproductive superiority (i.e., high fecundity and inclination to spawn in captivity) during previous spawning seasons. Malformed, diseased, and aged brood fish are regularly culled. Marking individual brood fish, or fin clipping year classes and/or sexes, and keeping accurate fecundity records are positive steps toward establishing a proper selective breeding program. Recruits, frequently called "selects" because they are the most rapidly growing young-of-the-year fish, annually replace 10-30% of the older brood fish (Snow et al. 1964). However, often the largest fingerlings are cannibals, and it may be more desirable to select for color, body proportions, performance on a prepared diet, etc. If little thought goes into brood stock selection, expect little improvement. Brood stock are usually replaced after they have spawned for three or four years because as they get older their spawning is less certain and they become more difficult to handle due to their large size.

Brood fish are kept in "holding" ponds, where they are usually fed forage such as goldfish, *Carrasius auratus* (Weibe 1935), or tilapia (*Tilapia* sp.) introduced at the rate of 5 pounds (2.27 kg) per pound (0.45 kg) of brood fish (Snow 1975). Snow (1971a) supplementally fed brood fish with Oregon Moist Pellet (Hublou 1963), and even reared brood fish through their seventh season exclusively on it without causing discernible differences in fecundity between bass fed OMP and others fed forage fish. The brood fish should gain 50-100% in body weight each year to insure their health and improve their reproductive potential (Snow et al. 1964).

Prevention of early spawning adds considerably to the overall success of bass propagation. The three most common ways to prevent premature spawning in holding ponds are to sort brood bass by sex (Snow 1965; Parker 1971) into different ponds, crowd them by dropping the water level in the holding pond (Snow 1965, 1969, 1970), or run cool water into the pond. These measures must be taken prior to normal spawning time. If past records are not available, we suggest using water temperatures of 56 F (13 C), 58 F (14 C), and 60 F (16 C) as being pre-spawning temperatures for smallmouth, spotted, and largemouth bass, respectively. At slightly warmer temperatures and as days lengthen (Caldwell et al. 1957), male bass will signal the approach of spawning by preparing excavated depressions used as nests (Manual of Fish Culture 1900; Snow 1975). However, early nests are often lost to cold fronts passing through, lowering water temperatures which results in male bass deserting the nest. Renesting will occur but production will be lower. Also, when early nests are successful, older and hence larger fry become mixed with younger and smaller fry from later spawns. Cannibalism is certain to abound in that situation. In addition, spawning season for black bass can last 6 to 10 weeks, but by delaying spawning until ideal conditions exist, spawning occurs within 24-48 hours. What would be a long ordeal for hatchery workers can be reduced to several days, and fry are more likely to be uniform in size and can be distributed or transferred to rearing ponds with minimal losses to cannibalism and grading. Again consult past records for peak spawning times and temperatures, but if necessary use 66 F (19 C), 68 F (20 C), and 70 F (21 C) respectively for smallmouth, spotted, and largemouth bass. Even at these water temperatures it is desirable to contact the National Weather Service before stocking brood bass for the possibility of cold fronts for a week. Adult bass can be held without spawning until appropriately stable spawning conditions persist (Jurgens and Brown 1954; Jackson 1979).

Spawning

Although artificial reproduction of largemouth bass is feasible (Birge 1907; Stevens 1970; Wilbur and Langford 1974; Smith et al. 1977), current cultural limitations in other phases of largemouth bass culture prevent its practical employment. Therefore, largemouth bass fry are still obtained in the traditional manner (Manual of Fish Culture 1900; Davis and Weibe 1930; Meehan 1939; Blosz 1948, 1952; Topel 1949; Bishop 1968; Snow 1970, 1975). Huet (1970) described this method as "controlled, natural reproduction."

Preparation of the spawning ponds depends on which of the two basic methods of spawning and fry-rearing is to be used: spawning-rearing or fry-transfer. Only casually mentioned here is the spawning-rearing method, which is labor extensive and requires fewer ponds because fry remain in the spawning ponds, usually with the brood fish, until they are removed for distribution or further feeding at a length of 1.5-2.0 inches (38-51 mm). Therefore, pond fertilization is required and brood fish stocking rates are lower than those used in the fry-transfer method. With the assumption that sex ratios will be tolerable, "pond run" brood bass are stocked at 20 fish/acre (50 fish/hectare). With this method fry production per unit area is much lower and less predictable, and fry size is less uniform than when the fry-transfer approach is used (Snow 1970, 1975; Huet 1970).

For the fry-transfer method (Manual of Fish Culture 1900; Snow 1975), ponds of 1-4 ft or 0.33-1.33 m (Carr 1942), an area of 0.75-1.5 acres or 0.3-0.6 ha (Snow 1970), and protected from the wind are good choices for spawning. Ponds with histories of good production should be selected. During the fall and winter, ponds are drained, dried, and disked. McCraren (1975) suggested that a treatment with an approved, pre-emergent herbicide for 7 to 10 days before spring flooding helps control rooted vegetation, which otherwise inhibits fry removal. Huet (1970) reported that some culturists place gravel in selected sites about the pond to facilitate fry collection by inducing nesting and spawning within confined areas. Even though gravel is preferred, it is not necessary for any of the black bass species. Chastain and Snow (1966) and Inslee (1975) have used portable spawning mats successfully, but supporting technology has not encouraged proliferation of this technique. Since fry are removed soon after hatching, pond fertilization is not necessary and, in fact, interferes with fry harvest. Phytoplankton blooms resulting from fertilization reduce visibility and thus restrict sighting schools of fry for removal.

Well-formed, healthy, ripe brood fish should be selected (Snow 1965). Maturity depends on size rather than age (Moorman 1957). In the South, a bass may mature at 8 months to 1 year of age, at a length of 8.0-9.0 inches (22-24 cm) and a weight of 0.4 lb (0.18 kg) (Swingle 1950). A prophlactic pond treatment helps reduce ectoparasites from brood fish prior to removal from the holding pond. Following capture, it may be beneficial to dip them in an approved chemical to remove remaining parasites.

Stocking rates and ratios are points of dispute; preferences are based on experience and the results desired in a particular situation. Brood fish stocking rates depend on number of fry required and reproductive potential of the brood fish. Reproductive potential is determined by previously mentioned characteristics that one considers when selecting broodstock. Stocking too heavily (Birge 1907; Snow et al. 1964; Snow 1969, 1970) not only reduces egg production of individual fish, but may also prevent some bass from spawning. Bishop (1968) reported that overstocking reduced production by smaller brood fish. At Federal warmwater hatcheries 40-100 adults/acre (100-250 adults/hectare) are stocked depending on size of the fish; for instance, 35 to 40 fish weighing 3-4 lb (1.4-1.8 kg) or 70-80 fish weighing 0.75-1.0 lb (0.3-0.5 kg) would be stocked per acre. To stimulate spawning, the fish culturist should place brood fish in the spawning ponds while they are being filled (Bishop 1968). A female bass will not release all eggs at a time, and one female may spawn in more than one nest during a short period. In order to have nests receiving all eggs potentially available, plenty of males are needed (Snow 1970). Bishop (1968) recommended 2:1 and 3:1 male to female ratios; other culturists have used three males to two females. Snow et al. (1964) suggested stocking adults of the same year class together because they are more likely to spawn at the same time and produce fry of the same size. No forage fish are placed in spawning ponds because they would compete with fry and perhaps be a source of disease.

Bishop (1968) reported that female bass are capable of producing 900-79,820 eggs/lb (2,000-176,000 eggs/kg) of body weight. Snow (1970) found that females lay an average of 25,000 eggs/lb (55,125 eggs/kg) of body weight. Huet (1970) wrote that bass eggs are 0.06-0.1 inch (1.5-2.5 mm) in diameter and that size increases with the size of the producing female. Snow (1971a) reported that an average of 5,000-43,000 eggs were laid in a nest, and in 1973 he said that 78% of the eggs hatched and about 58% of the fry survived to the swim-up stage.

Hatching and development time are primarily a function of temperature. Snow et al. (1964) stated that hatching occurs 48-96 hours after spawning and that the transparent fry are about 0.16 inch (4 mm) in total length. At this point, fry are at the bottom of the nest, where they disperse among the stones and other substrate material. Between the fifth and seventh day, bass fry become pigmented. They have then consumed the nutrients of the yolk sac and with the first filling of the gas bladder (Johnston 1953) rise from the nest in a school to make their debut as predators. As swim-up fry, bass consume such zooplanktors as cladocerans, rotifers, and copepods. Although fry abandon the nest 8 to 10 days after hatching, they are guarded by the male parent as long as the school remains intact. Bass fry can be moved to rearing ponds any time after they leave the nest, but to avoid injury to the delicate fry, it is advisable to wait until they are 0.6-0.8 inch (15-20 mm) long, a size reached in 10 days to 4 weeks after hatching, depending on water temperature (Snow et al. 1964). When food in the spawning ponds becomes scarce, fry must be removed regardless of size. It is possible to harvest 500,000 fry/acre (1,234,000 fry/ha), although Snow (1975) believed that half that number is a more realistic expectation.

Rearing

It is advantageous to capture fry before the schools break up. For intensive feeding indoors, fry from different schools should not be mixed.

For the first few days after swim-up, fry are relatively slow swimmers and they stay pretty close to the nest site. For those few days it is easy to place separate tubs of water on the pond bank close to the schools of fry to be harvested. While the sun is shining the fry will be near the surface of the pond. Several quick dips with a long handled net covered tightly (no bag) with window screen will capture several hundred fry which are placed into the appropriate tub. Move on to another school of fry and do the same thing. Continue on to another school, etc. Within an hour schools should again be collected near the pond surface for easy harvest and placement into appropriate tubs. Water in the tubs will warm rather quickly. Pouring a bucket of fresh water into the tub will make the fry go to the bottom of the tub. Water can then be easily skimmed from the tub and changed. Although size difference is always a problem in bass culture, it is slightly less important in pond rearing. Therefore, faster methods of removing fry that do not keep schools separate are used. While still in schools bass fry can easily be captured by two people in a small boat. When a school is sighted, a fine-meshed seine (similar to cheesecloth) is passed under the school and lifted into the boat. The fry are then washed from the seine into a tub of water. More frequently, fry are seined by two people wading. A weight, such as a stone, is often placed in the seine as the fry are being removed to keep the wind from overturning the seine and allowing the fry to escape. Clear, calm water, free of debris and vegetation, facilitates the sighting and removal of fry. To improve visibility on windy days, the application of vegetable oil on the surface of the pond creates a slick that retards the rippling caused by the wind. Of course wading during seining muddies the water, making observation of schools difficult. (Fry are attracted to light -- a factor which may be used to advantage in night harvesting). If not removed, the growing fry will exhaust the pond's ability to produce enough food for them. The schools thus break up to forage for sustenance and can often be seen cruising along the shoreline in their search. At this time, trapping with such devices as a glass-V trap (Anonymous 1951; J. R. Anderson 1974) may be an effective method of harvest. Fry not removed from spawning ponds are allowed to remain for additional growth after which they are removed with the brood fish.

At the A. E. Woods State Fish Hatchery, San Marcos, Texas, largemouth bass fry are produced and harvested in a somewhat different manner. As in the method just described, brood bass are discouraged from premature spawning in the holding ponds until the danger of cold weather is reduced. The brood bass are then selected and stocked in spawning ponds where they begin nest building and spawning within 24 hours; in about 30 days the first crop of 0.5-0.75 inch (13-20 mm) fry is harvested. However, instead of the bass being removed intermittently and incompletely by "spot" seining, they are removed in a single operation. The ponds are drained, and the fry are collected in the catch basin. Chicken wire screens prevent brood bass from entering the catch basin. Following fry removal, brood bass are taken out and placed in holding facilities. The pond is refilled within 24 hours, the brood bass replaced, and a second spawn produced. So long as food organisms for fry are plentiful, fry produced in this manner are of uniform size at harvest. Pat Hutson, the hatchery manager, feels this method reduces cannibalism, as well as the time and labor required.

After bass fry are harvested, cannibals are removed (Stranahan 1906). The fry should also be cleaned of debris and sorted into groups of similar size. Their numbers are then estimated by one of several methods. Snow (1975) suggested that it be done "visually by counting a sample into a container. Similar containers receive uncounted fish until the unknown compares in appearance to the counted standard. Weight or volume based estimates can be obtained by counting the number of small fish in a weighed or volumetrically measured sample. The number-weight or number-volume relationship is then used to calculate the quantity of fry needed for stocking the rearing pond. If properly applied, any of these techniques should enable the bass culturist to know within 10% the number of fry stocked." The visual method is least harmful to fry and often is as accurate because a few drops of water transferred in weights or volume measurements create large errors when counting tiny fish.

Preparation of fry rearing ponds begins well in advance of the stocking date. According to Bishop (1968), rearing ponds should be drained after the summer or fall fingerling harvest, exposed to sunlight and atmosphere, and disked. The pond bottom should then be sown with winter rye, to produce a dense growth of vegetation which, upon its decay after spring flooding, will produce prolific zooplankton populations to sustain the fry. Rearing ponds should be full 2-3 weeks before stocked. If filled with well water, innocculate with plankton from another pond. After the rearing ponds have been flooded and the first spawns are produced in the spawning ponds, the ponds need additional fertilization. Snow (1970) suggested the use of an "(in)organic nitrogen-superphosphate combination at a rate of 8 lb/acre (9 kg/ha) nitrogen and 8.4 lb/acre (9.0 kg/ha) phosphate per application at weekly intervals until an abundant zooplankton population develops. Ordinarily this will require three or four applications. Following ample plankton development, biweekly applications of fertilizer should be made until about ten days prior to the expected harvest of the fingerling bass."

Some ponds may have other uses that preclude growing a crop of winter rye. In those situations some type of organic matter should be added prior to filling to give zooplankton an immediate start. Local products such as manure, peanut hay, alfalfa cubes, etc. can be used at rates up to 1,500 lb/acre (1,684 kg/ha). Be conservative the first time organic fertilization is tried. Decomposition of organic material can result in oxygen depletion. It helps avoid oxygen depletion to put organic matter in piles rather than scatter it over the entire pond bottom. If aquatic vegetation becomes started, no further application of any kind of fertilizer should be made until the plant growth is killed with a herbicide because further fertilization will just grow more luxuriant plants. Bishop (1968) wrote "the zooplankton explosion should be correlated with that of the fry, requiring very precise timing." Editorially, we add that considerable luck is also needed!

Snow (1970) suggested stocking bass fry at 50,000-75,000 fish/acre (123,550-185,320 fish/ha) whereas McCraren (1975) and Millard (1978) recommended a rate of 100,000 fish/acre (247,000 fish/ha) if 1-2 inch (25-51 mm) fish are desired. The time required for fry to reach that size depends on their size when stocked, stocking density, pond productivity, and water temperature. Snow et al. (1964) reported that fingerlings can be 1.5-2.0 inches (38-51 mm) long in 2-4 weeks in the southeastern part of the United States when water temperatures are 70-80 F (21-27 C). While fingerlings are in rearing ponds, good management techniques are necessary for maximum production: among those to be emphasized are proper fertilization; control of vegetation, predators, and disease; and maintenance of adequate water quality. In any event, fingerlings should be moved when their rate of growth is noticeably reduced and size variation becomes pronounced. These signs indicate that the pond has reached its carrying capacity. The fingerlings may be harvested by seining, trapping, or draining, or by a combination of methods.

Assuming that production in the rearing pond was fruitful, a pond may be expected to yield 30-150 lb/acre (34-168 kg/ha) of 1.5-2.0 inch (38-51 mm) fingerlings. Bass culturists should strive for a survival between 75 and 90% of the number stocked, but the average is around 70% (Willis and Flickinger 1980). Snow (1975) wrote that if survival is less than 75%, improvement in fry enumeration, better zooplankton production, or more efficient control of disease, predators, and competition should be stressed.

Training

In those instances where bass over 4 inches (100 mm) are desired or where rearing pond space is limited, supplemental feeding is now a practical solution. In the past bass fingerlings have been trained to consume ground fish, beef heart, pet food, and a variety of other meat products; production has always been limited and unpredictable (Langlois 1931; Snow, 1960, 1969; Snow and Maxwell 1970). Often the diets were nutritionally inadequate or unpalatable, and supplies undependable. The Oregon Moist Pellet Diet (OMP) and more recently Biodiet have changed intensive feeding of black bass. Both Ashley (1974) and Nagle (1976) found OMP to be a better ration than commercial dry diets. Willis and Flickinger (1981) could detect no difference between Biodiet and OMP. Biodiet requires no refrigeration and thus may be more suitable for long distance shipping and storage at the hatchery.

With present technology, bass greater than 3/8 inch (10 mm) can be trained to accept a semi-moist diet. Later, trained fingerlings can be graduated to a dry diet. Much of what is about to be summarized is directly from research projects. It has worked on one strain of bass under a particular set of conditions. Use the information as a base, but be encouraged to modify for your circumstances.

Fry Training

For intensive bass culture, fry are those fish ranging from 3/8-3/4 inch (10-20 mm). Carp eggs (*Cyprinus carpio*) have been the only successful training food for bass in this size range (Brandenburg et al. 1979; Murphy 1980; Willis and Flickinger 1981). Eggs from small carp are about 1 mm in diameter, and eggs from large carp can be 2 mm in diameter. Bass fry of 10 mm can barely swallow 1 mm eggs. Therefore it is imperative that fry less than 10 mm not be harvested from spawning/rearing ponds and that only eggs from small carp be used when 10 mm bass are being trained. At this size bass grow about 1 mm/day, and it is well worth the extra couple days to get a little more size on the fry before training. The other prerequisites to successful fry training are covered circular tanks or short troughs, and heated (72 F or 21 C) well water; it is desirable to rear only siblings in the same container to reduce cannibalism (Willis and Flickinger 1981).

Fry are placed into tanks or troughs at densities approximating 565 fry/ft^3 (20 fry/litre). The rearing containers should be covered with black plastic, but several slots can be cut to facilitate feeding. Removing the covers during cleaning has no discernable effect on the fry. Water temperature should be 72 F (21 C) and be exchanged at least once per hour; more often is preferable. Be alert to nitrogen supersaturation when heating water, and take steps to eliminate it. Also be prepared to use window screen on outlets initially; later 1/8 inch (3 mm) hardware cloth will be suitable screening material.

Fresh carp eggs are easier to work with but separated carp eggs can be fast frozen in advance of the training period. If the eggs are not frozen quickly, the chorion ruptures and the yolk is lost. Gently rubbing the removed ovaries over a piece of 1/8 inch (3 mm) hardware cloth placed over a bucket with a stream of water falling in the vicinity of the ovary is a satisfactory way of separating single eggs. Once separated the eggs should be rinsed and finally most of the water should be poured off. To feed carp eggs to bass fry, suck up a quantity of eggs and water into a meat baster, and then squirt some eggs through feeding slots cut in the plastic covers. As the eggs are consumed, add some more. It is important to have some depth (at least 12 inches or 300 mm) and turbulence to the water to keep the eggs in suspension for awhile. Bass will not eat eggs from the bottom of the tank. Feeding every hour for 12 hours is better than feeding every 3 hours for 12 hours (Willis and Flickinger 1981). Troughs must be cleaned daily and there should be some uneaten eggs on the bottom to insure that an abundance of eggs have been offered. As a guide, 50,000 bass fry require eggs from the ovaries of approximately 20-25 carp of 3-5 lb (1.4-2.3 kg) each day. After 4 or 5 days of feeding carp eggs, bass fry should be actively feeding on eggs. Over the next 3 or 4 days, increasing amounts of a semi-moist diet should be offered. Carp eggs and the commercial diet can be offered alternately at each feeding, or they can be mixed in a water solution just prior to feeding. The particles of prepared feed seem to maintain their integrity if the solution is not stirred too much. Particles in the 1.0-1.25 mm size range work well for fry training. Bass that have not learned to accept the prepared feed will starve in about a week's time. Consequently, any bass alive after 10 days should be trained feeders. Some bass will develop scoliosis from a tryptophan deficiency in carp eggs, but their backs will straighten after several weeks of eating the semi-moist diet (Willis and Flickinger 1981).

Cannibalism can start very easily with growing and starving bass in the same confined area. Once the training period is complete, bass fry should be graded; an 8 or 10 grader should be appropriate for removing cannibals. Another grading should be made in another 7 to 10 days through 10, 12, and 14 graders to get similar sized feeders together. At this point trained bass can be stocked into ponds or raceways for rearing on semi-moist or dry diets (see Grow Out). Expect at least 50% of the fry to train and 90% success has been attained.

Fingerling Training

For purposes of this section, bass of 1.5-2.0 inches (35-50 mm) are considered fingerling. (Bass between fry and fingerling sizes should be trained with a mixture of carp eggs and ground carp flesh.) This size range differs from fry in their ability to consume more food when feeding and to withstand starving for a longer period of time. Consequently, fingerling bass need to be fed only every three hours, five times a day. Also, nonfeeders at the end of the training program are sufficiently healthy to be put through training again, and many of them will learn to accept pelleted feed.

After 1.5-2.0 inch (38-51 mm) fingerlings are brought in from rearing ponds, they are cleaned of foreign material, prophylactically treated with an approved chemical for parasites, and graded to remove cannibals and establish uniform size classes; a sample is counted and weighed. The fingerlings are closely confined, initial densities being 0.25-0.50 lb/ft^3 (3.89-7.77 kg/m^3) of rearing space (troughs, circular tanks, raceways or cages). Flickinger and Langlois (1976) established densities of 3.0 lb/ft^3 (48.06 kg/m^3). The important point is that crowding the fish, and providing a single source of food so alters their environment that bass fingerlings are forced to modify their behavior correspondingly to survive. Crowding increases competition for food, which in turn encourages fingerlings to learn to accept the pelleted diet. Their seeing other fish feeding on what has been given aids their learning to accept the feed. Sufficiently high training densities can be maintained only as long as water quality remains acceptable. Westers and Pratt (1977) and Westers (1978) designed hatchery criteria for intensive salmonid production that, for the time being at least, can also be applied to the intensive culture of largemouth bass. They suggested an ideal flow rate through the culture units of four exchanges per hour. As long as the effluent contains no less than 5.0 ppm (5.0 mg/l) dissolved oxygen and no more than 0.0125 ppm (0.0125 mg/l) un-ionized ammonia, exchange rates could conceivably be somewhat less than four exchanges per hour. At the San Marcos National Fish Hatchery and Development Center loading rates of about 0.3 lb/ft^3 (4.95 kg/m^3) and exchange rates of two or three per hour are typical. The ideal water temperature during training, according to Nelson and Bowker (1974), is 78 F (26 C). Snow (1975) has had good training success at water temperatures of 77-86 F (25-30 C). Lower water temperatures (constant

72 F or 21 C) at San Marcos are not optimal and since feeding in fish is temperature dependent, may somewhat reduce training success. In addition to dissolved oxygen, un-ionized ammonia, and temperature, other water quality characteristics to be monitored are pH and carbon dioxide. Culture units should be cleaned daily to maintain adequate water quality.

Highest training success will be achieved by using a training sequence (R. J. Anderson 1974). One sequence that has worked is included here, but feel free to make adjustments.

Day	Food	Amount	Reason
1	fresh ground carp flesh	all they will eat 5 times/ day	To get the bass to accept something that smells, tastes, and has same texture as what they might eat naturally but is not alive.
2	fresh ground carp flesh	all they will eat 5 times/ day	To further reinforce above; by the end of day 2 bass will be fighting over the ground carp.
3	frozen ground carp flesh	6% body weight divided into 5 portions	To give coldness that OMP will have and to not stuff the bass to lethargy.
4	90% ground carp flesh and 10% OMP ground together	6% body weight divided into 5 portions	To introduce the taste and color to OMP.
5	80% ground carp flesh and 20% OMP ground together	Same as above	To further bring out the taste and color of OMP.
6	2/3 - 80-20 mix above and 1/3 OMP pellets	6% body weight of combined divided into 5 portions	To offer straight OMP to those that are ready for it and to coax the others for another day.
7	1/3 - 80-20 mix and 2/3 OMP pellets	Same as above	To get most of bass on OMP but to also make one last try to get the reluctant ones "with the program".
8, 9, 10	OMP pellets	6% body weight per day divided into 5 portions	To make sure the feeders will be plump and the nonfeeders will be skinny for easy sorting.

The proportion of bass feeding at the conclusion of this phase is the only valid measure of achievement. In fact R. J. Anderson (1974) defined "feeding success" as number of feeders/number of fish at beginning X 100. Feeders and nonfeeders are separated on the basis of plumpness and emaciation. One should expect 90% of the bass fingerlings to be trained by this sequence. The excess amount of feed fed at this time should be of little concern (if it is removed when cleaning), since its relative cost is small (Flickinger et al. 1975). If there is no excess feed, the fish are not being fed enough.

If it is not possible to obtain enough carp (50,000 bass fingerlings will require about 12 lb (5.4 kg) of fillets per day) or to grind fish at your facility, some strains of bass train quite readily onto a semi-moist diet. The following method should serve as a guide. After an acclimation period of 24 hours (McCraren 1975), the training period of 2-3 weeks begins. The feeding regimen is extremely important because it determines to a great extent the number of fish accepting feed. Only fish learning to accept the formulated ration will live to become advanced fingerlings. The more often fingerlings are fed at rates of at least 15% of their body weight per day, the more often they come in contact with pellets and the greater their opportunity to learn to accept them. Feeding eight times a day, seven days a week during the training phase is not excessive. Feeding during this phase must be performed in a deliberate, methodical manner. Broadcasting feed around the culture units increases exposure of all fish to pellets. More research needs to be done with automatic feeders during the training phase, but to date, hand feeding has provided better results. Initial size of the OMP pellet is 1/16 inch (1.6 mm). Sizes of pellets are increased to 3/16 inch (4.8 mm) in accordance with the increase in growth of fingerlings. If fingerlings accept the pellet reluctantly, it may be advantageous to feed a little ground fish along with the pellets. If the amount of ground fish is then gradually reduced, fingerlings can be "weaned" off it as they learn to accept the pelleted ration.

Constant vigilance during the training phase is essential. Grading must be done when necessary to maintain uniformity among fingerlings. Any diversity in size encourages cannibalism, which is turn reduces training success. Cannibals, which can be discerned by their disproportionate size or by direct evidence (e.g. the tail of a victim protruding from the mouth) should be removed immediately. Caution must be exercised when bass are graded because grading inevitably causes stress and physical damage to fingerlings.

Other than starvation and cannibalism, disease is the most serious cause of mortality. If diseased fish are not treated, losses can be catastrophic. The most serious offender at the San Marcos facility, as well as at other intensive culture facilities, is Flexibacter columnaris or "saddle-back." This myxobacterium is ubiquitous and becomes a problem whenever bass are stressed. Bass held at high densities during the training phase should be considered continuously stressed. Daily prophylactic treatments may be necessary to prevent a columnaris outbreak, and sanitary practices must be persistently observed. Physical damage sustained during grading or from nipping and biting cannot be entirely eliminated; however, one must be perpetually aware of the very fine line between health and disease under these conditions.

If possible, "feeders" and "nonfeeders" should be separated (nonfeeders are easily distinguishable by their emaciated appearance). This separation appears to dissolve the established "peck order" and may result in as many as 75% of the nonfeeders eventually being trained. At the end of the training period, as many as 65-95% of the fingerlings will be trained, and they will have doubled their weight (Snow 1975; McCraren 1975). Before the trained fish are transferred to "grow-out" units, they must again be graded into uniform lots, weighed, and counted to determine feeding success and to establish a new number/weight relationship.

In summary, training success depends on initial size and condition of fingerlings, a nutritionally adequate and palatable diet, appropriate sized feed, feeding regimen, strain of bass, grading, eliminating cannibals, disease prevention and control, adequate quantity and quality of water, experience, and luck. Do not depend on luck!

Grow Out

Once bass accept feed, they retain the learned behavior indefinitely (Nagle 1976; McCraren 1974; Flickinger et al. 1975). Fortunately this enables the culturist to complete the propagation of fingerlings entirely on a pelleted ration. After fry or fingerlings are trained, they are transferred in similar-size lots to "grow-out" ponds. A minimum stocking density is 10,000 bass/acre (24,700 bass/ha), and up to 120,000 bass/acre (296,400 bass/ha) may be permissable if adequate water is available and final size is not too large. A pond carrying capacity of 2,000 lb/acre (2245 kg/ha) is possible. Bass may also be reared to the desired size in warmwater raceways, as is done at the San Marcos Center. Snow and Wright (1976) successfully reared bass in cages.

After fingerlings have been tempered to avoid temperature shock, they are placed in the pond. Feeding must take place around the pond perimeter until the fingerlings learn to associate feed with the person feeding. After that they will approach the person fearlessly from all areas of the pond. For visibility it is important that the rearing pond be relatively small. Fingerlings often segregate into two populations at either end and must be fed accordingly. During the first ten days, bass fingerlings are fed four times daily, 1/8-inch (3.2 mm) OMP at 15% body weight/day. This amount can be varied to accommodate the appetite of the fish. For the next week the amount fed is gradually reduced to 5% body weight/day. For the next 30 days the fingerlings are maintained at a constant rate of 5% of body weight/day divided in two feedings. Sylvia (1981) has proposed a feeding chart for bass (Table 1). When fingerlings reach 4 inches (102 mm) in length, their diet is changed from 1/8-inch (3.2 mm) OMP to Purina Floating Trout Chow No. 6. Nagle (1976) found that a dry diet reduced labor and feed costs with no reduction in growth rate. Some strains of bass accept an immediate change to a dry diet and other strains require a gradual change over several days. According to McCraren (1974), "At Marion (Alabama) a stocking rate of 10,000 (fingerlings)/acre (24,700 fingerlings/ha) produced bass averaging 8 inches (20 cm) in total length and weighing approximately 4/lb (9/kg). This was accomplished in about 100 days at an average water temperature of 80 F (27 C). A survival rate of 80% can be anticipated, as well as a conversion of 1.5." McCraren (1974) has estimated the feed requirements for rearing 20,000 8-inch largemouth bass as follows: 100 lb (46 kg) 1/16" OMP, 300 lb (136 kg) 3/32" OMP, 600 lb (272 kg) 1/8" OMP, and 3000 lb (1364 kg) No. 6 trout chow.

Before fingerlings are placed in the "grow-out" pond, an application of an approved pre-emergent herbicide is recommended. This application will help reduce harvesting problems associated with rooted vegetation, which can spread prolifically in ponds greatly enriched as a result of heavy feeding. Periodic treatments with copper sulfate (treatments depending on water quality) to control filamentous algae are also suggested.

Inspection of fingerlings for parasites and prophylactic pond treatments should be carried out routinely. Monitoring water quality should be done regularly, but certainly if oxygen depletion problems threaten. Pumping ample supplies of good quality water into a pond, in conjunction with use of aerators if necessary, can yield immediate relief if dissolved oxygen levels become dangerously low. Oxygen depletion typically occurs on hot, calm, cloudy days, particularly early in the morning, in ponds with thick vegetation, high densities of fish, and heavy feeding rates. The fish do not feed actively, swim erratically near the surface, and flash quickly away when approached. The good management practices employed in other types of pond fish culture operations will serve the culturist in good stead during this "grow-out" phase.

Using the Marion Program, McCraren (1974) reported "our hatcheries (Federal) at Inks Dam and Fort Worth, Texas, and Tishomingo, Oklahoma, produced over 35,000 bass weighing approximately 12,300 lb (5,578 kg). Best success was obtained at the Texas hatcheries where six ponds averaging 0.6 surface acre (0.24 ha) each yielded bass averaging 2.5/lb (4.41/kg) at approximately $1.00/lb for feed, labor and chemicals. During the pond-rearing period of nearly 150 days, Inks Dam Hatchery recovered 80% of the bass it stocked." A similar effort at the London (Ohio) Fish Hatchery produced 26,102 yearling bass weighing 7,598 lb (3,445 kg) in 1.6 surface acres (0.68 ha), or the equivalent of 4,550 lb/acre (5,100 kg/ha), during 1973, 1974, and 1975 (Nagle 1976).

Table 1. Hypothetical bass feeding chart incorporating optimum feeding frequencies.

Total Length (mm)	Average Number per kg	12	15	18	21	24	27	Feeding Frequency (times/day)[a]
	Average Daily Water Temp. (C) →	Percent of Body Weight to Feed Daily						
20	8000	3.5	4.5	9	16	18.5	20.5	12
26	4000	3	4	7.5	14	16.5	18.5	
33	2000	2.5	3.5	6	12	15	17	8
43	1000	2	3	4.5	10	13	15	
58	500	1.5	2.5	4	8	11	13	5
72	250	1.5	2	3	6	9	11	
87	125	1.0	1	1.5	4	7	9	3
93	75	.5	.5	1	3	5	7	
112	40	.5	.5	.5	1.5	3	5	2
130	20	.4	.5	.5	1	2	3	
160	10	.4	.5	.5	1	1.5	2	1
210	5	.3	.4	.5	.5	1	1.5	
300	2	.3	.3	.4	.5	.5	1	
400	1	.2	.2	.3	.4	.5	1	

[a] Feeding during 12 h daylight period.

Over-wintering

At present management biologists in several states are experimenting with stocking Age I bass. If successful, hatchery personnel will be asked to carry large numbers of bass through the winter. Preliminary information on this subject has been gathered at San Marcos and at Colorado State University. Of significance to readers is the finding that bass can be fed long into the fall until water temperatures consistently stay below 50 F (10 C). On marginal days, one should feed during mid-afternoon when the warmest temperature is likely to occur. Bass fingerlings will not only maintain themselves, but show some growth at cold temperatures. Intuitively it still seems best to add some fathead minnows (*Pimephales promelas*) to bass rearing ponds after water temperature have become too cold for pellet feeding; however, statistically there is no difference between bass with fathead minnows and bass without fathead minnows. An average survival of 75% can be expected. When waters warm to 50 F (10 C) in the spring, bass yearlings will again accept pelleted feed.

Summary

If the demand for advanced largemouth bass fingerlings continues to increase, development of improved intensive culture methods among Federal, state, and commercial producers must keep pace. The foundation has been laid with the significant advances of the "Marion Program" and the use of an adequate formulated diet. Further developments are in progress, with emphasis in the following:

Nutrition - Improved economical diets formulated to meet the specific nutritional needs of largemouth bass are needed. Refinement of feeding rates and frequencies for largemouth bass of different sizes under different culture conditions is desirable. The feeding success of fry may be increased by such methods as "microincapsulation" and mass culture of invertebrate food organisms that constitute the natural source of fry nourishment.

Disease Control - Prophylaxis and disease control depend on the development of new drugs and chemicals for chemotherapy, antibiotics, vaccines, fungicides, parasiticides, etc. For example, the development of a bacterin for Flexibacter columnaris would constitute a major breakthrough in fish health.

Behavior - Ethological studies of feeding responses, response to stress and stimuli under intensive culture conditions and behavior modification, as well as clarification of the "critical period" hypothesis would be beneficial.

Physiology - Observation of physiological responses to stress during intensive cultivation, harvest, and transport would illuminate areas for improvement.

Equipment design and utilization - Always welcome are improvements in fish handling equipment and techniques of sampling and counting (number and weight estimation, particularly of fry); maintenance of suitable environmental conditions; grading (especially of fry); disease treatments; feeding (automatic feeders); harvesting; loading; transporting; and marking.

Strain Development - The development of a strain amenable to the rigors of intensive culture is logical if production quotas are to be satisfied. Rational selection of such a strain could be expected to produce a fish capable of (1) accepting a formulated feed at a smaller size in larger numbers; (2) growing rapidly and having superior conversions; (3) developing disease resistance and tolerance to the stressful conditions inherent in high density culture; and (4) growing more uniformly and with a reduced tendency toward cannibalism.

Other subjects of interest concern maximum loading densities and stocking rates in culture units as well as in the wild, and survival of advanced largemouth bass fingerlings raised intensively when stocked in the wild.

Success in rearing advanced largemouth bass fingerlings has developed only recently, although the ideas and impetus behind it have existed for years. Continued success depends upon demand, and the originality and determination of fish culturists and biologists in meeting the demand with improved techniques.

SUNFISH

Much less research has been conducted on propagation of the various sunfishes. Persons involved with raising these fish have "gotten by" with extensive culture techniques. References pertain to bluegill (*Lepomis macrochirus*) and redear sunfish (*L. microlophus*), but we suspect that the techniques suggested could apply to any lepomid.

Broodstock

Bluegill at least two years old (Higgenbotham et al. n.d.) and 5-7 inches (12-18 cm) long weighing 0.2-0.3 lb (100-150 g) are suitable brood fish (Huet 1970). They can be maintained on pelleted feed (Higgenbotham et al. n.d.) (this is not true for other sunfish). All sunfish spawn several times during the summer. Male sunfish aggressively defend the small excavated depression used as a nest site, but nests are often in close proximity.

Spawning

As water temperatures warm to 70 F (21 C) spawning activity begins, and brood stock should have been stocked previously. The number of brood fish stocked is governed by the size of fingerlings desired because young and adults are generally left in the spawning/rearing pond. Blosz (1948) recommended stocking 100 brood fish/acre (247 fish/ha) with an expected yield of 150,000 one-inch fingerlings/acre (370,500 twenty-five-millimeter fish/hectare). He also stated that with 30 broodfish/acre (74 fish/ha) 50,000 fingerlings/acre (123,500 fish/ha) averaging 300 fish/lb (660 fish/kg) would be produced. Surber (1948) reported a harvest of 274,000 small fingerling bluegill/acre (676,780 fish/ha) from a stocking of 80 brood fish/acre (198 fish/ha). Higgenbotham et al. (n.d.) wrote that "375,000 fry/100 broodfish has been achieved." Finally Huet (1970) generalized that a stocking of 80-120 pairs/acre (200-300 pairs/ha) would produce 162,000 fingerlings/acre (400,000 fish/ha).

Huet (1970) and Higgenbotham et al. (n.d.) recommended stocking equal sex ratios but Davis (1953) suggested using two males to three females. Sexes may be sorted by methods described in McComish (1968). Incubation is less than 5 days (Huet 1970). Carbine (1939) reported 61,815 fry in one nest, with an average of 17,914.

Rearing

Because sunfish are not very cannibalistic and they are fragile at small sizes, young are reared in the spawning/rearing pond with adults. Consequently spawning/rearing ponds should be fertilized to enhance production of invertebrates. Readers are referred to the Rearing section under Black Bass for pond fertilization guidelines.

Bluegill readily accept pelleted feeds and thus supplemental feeding can be used to increase their production (Davis 1953; Higgenbotham et al. n.d.). Other sunfish, though, are reluctant to accept commercial rations. Bluegill do not move very far, and therefore food should be distributed all around the pond (Bennett 1970).

Hybrids

Although hybrid sunfish were more popular a few years ago, there is still some demand for them. The same general propagation techniques just summarized are also used to produce hybrid sunfish. Most critical to the production of hybrid sunfish is brood stock. In some areas of the U.S. enough natural hybridization has occurred that it is difficult to find pure stocks (Childers 1967). Crossing impure stocks does not give expected sex ratios. Also, it is critical that no errors be made when sorting males and females to be used in hybrid crosses; one error negates the whole effort.

Sometimes there are unexplained spawning failures; cutting off the opercular tabs on males may reduce the problem (Lewis and Heidinger 1978). Young hybrid sunfish can be fed supplementally if bluegill was one of the parents used (Lewis and Heidinger 1971).

CRAPPIE

From a management standpoint the black crappie (*Pomoxis nigrmaculatus*) behaves somewhat differently from the white crappie (*P. annularis*). However, in culture situations both are very similar.

Broodstock

Age I crappie, 5 inches (125 mm) long will spawn. In general, though, Age II crappie are used for spawning. Few crappie live past Age IV (Ming 1971). Large crappies feed on fish, but they also have the ability to exist on invertebrates (Ming 1971). Addition of fathead minnows to brood stock holding ponds would be desirable but not necessary.

Smeltzer (1981) discovered a way to distinguish male and female black crappie; portions of his methods should be applicable to white crappie. In a four step sequence nearly 100% accuracy was achieved. Step one consisted of selecting those fish with a deep black coloration; these fish were males and there were no errors in selection. Remaining fish were either females or males not in spawning condition. In step two fish were gently stripped to obtain sex products. Obtaining eggs was obviously an exact determination of a female. Remaining now were males and females that were not ripe. Step three is observation of the urogenital opening. Differences between male and female crappie are not as distinct as for bluegill, but they resemble the differences described for bluegill (McComish 1968). An occasional error can be made at step three with borderline appearances. Step four involved holding uncertain crappie from step three without food for several days. Then any distention in the abdomen above the urogenital opening indicated ovaries. There is no information to support stocking unequal sex ratios, but being able to sort male and female crappie allows the culturist to determine whether the brood stock being held is close to a normal sex ratio.

Spawning

Water temperatures in the upper 60's F (19 C) are a spawning threshold for crappie. At slightly cooler temperatures black crappie males will be colored, and males of both species will begin to be solitarily attached to a small area. It is difficult to generalize on stocking rates for brood fish because production has been variable and in many cases both species were stocked together or other species were included with crappie (Leary 1909; Davis and Wiebe 1930; Culler 1938; Harper 1938; Mraz and Cooper 1957; Smeltzer 1981). With some data to support his statement, Smeltzer (1981) wrote "brood densities greater than 247 per ha (100 fish/acre) seem to reduce production." Until further information is available, we suggest stocking adults under this density. Smeltzer (1981) reported by far the highest yeild of crappie - 66,680 fingerlings/acre (164,700 fingerlings/ha) from 51 adults/acre (125 adults/ha).

Although crappie are attracted to brush (Petit 1973), Smeltzer (1981) showed that brush is not necessary for spawning or survival of young crappie. Male crappie fan a poorly defined nest site which they attempt to defend, but their ability to discourage crayfish from eating eggs is questionable. Therefore it is recommended that crayfish be controlled if very numerous in crappie spawning ponds. Incubation time is 48 h at 66 F (19 C) (Seifert 1968).

Smeltzer (1981) found that it was difficult to remove all adult crappie after spawning, and concluded on the basis of stomach contents of adult crappie that incidence of cannibalism on their young was low and consequently their presence had little influence on production.

Rearing

Like sunfish, crappie spawning and rearing are accomplished in the same pond. Readers are referred to the Rearing section under Black Bass for pond fertilization guidelines.

Smeltzer (1981) evaluated the addition of fathead minnows to crappie rearing ponds. He found depressed yields and surmised that fathead minnows and crappie competed for zooplankton, and also perhaps adult crappie feeding on fathead minnows were more likely to opportunistically cannibalize young crappie.

The biggest problem in culture of crappie is harvesting. It has long been felt that crappie are extremely susceptible to Flexibacter columnaris (Davis 1953). In Smeltzer's (1981) research, he found that young crappie die with a "saddle-back" appearance resembling one of the signs of columnaris disease, but the cause of death was shock. A variety of additives to hauling tank water were of no value. However, nearly 100% survival was achieved by harvesting after dark.

Training

There may be little demand for advanced crappie fingerlings, but for the record Smeltzer (1981) found that crappie trained best (up to 95%) on a carp egg to Biodiet sequence similar to that used for small bass (Willis and Flickinger 1981). Crappie appeared to train on carp eggs to W-7 diet, but gradually rejected W-7. Biodiet alone had moderate success (54-61%) and W-7 alone was terrible (3-5%). He also reported about 25% poorer training success with 1.7-2.6 inch (45-65 mm) fingerlings than with 1.0-1.4 inch (25-35 mm) fingerling crappie.

Bibliography

Anderson, J. R. 1974. Glass V-trap. Prog. Fish-Cult. 36(1):53-55.

Anderson, R. J. 1974. Feeding artificial diets to smallmouth bass. Prog. Fish-Cult. 36(3):145-151.

Anonymous. 1951. Prog. Fish-Cult. 13(4):12.

Ashley, K. R. 1974. Commercial diets for largemouth bass. M.S. thesis, Colorado State University, Fort Collins. 63 p.

Beeman, H. W. 1924. Habits and propagation of the smallmouth bass. Trans. Am. Fish. Soc. 54:92-107.

Bennett, G. W. 1970. Management of lakes and ponds. Van Nortrand Reinhold Co., New York. 375 p.

Birge, E. A. 1907. Experiments in raising black bass by taking the nests away from the parents and hatching the eggs in troughs. Trans. Am. Fish. Soc. 36:154-158.

Bishop, H. 1968. Largemouth bass culture in the southwest. Pages 24-27 in Proc. North Cent. Warmwater Fish Culture Workshop. Ames, Iowa.

Blosz, J. 1948. Fish production program, 1947, in the southeast. Prog. Fish-Cult. 10(2):84-87.

Blosz, J. 1952. Propagation of largemouth black bass and bluegill sunfish in federal hatcheries of the southeast. Prog. Fish-Cult. 14(2):61-66.

Brandenburg, A. M., M. S. Ray, and W. M. Lewis. 1979. Use of carp eggs as a feed for fingerling largemouth bass. Prog. Fish-Cult. 4(2):97-98.

Brown, W. H. 1952a. Rate of survival of largemouth black bass fingerlings stocked in experimental farm ponds. Prog. Fish-Cult. 14(2):78-80.

Brown, W. H. 1952b. Rate of survival of largemouth black bass fry in experimental farm ponds. Prog. Fish-Cult. 14(4):177-179.

Caldwell, D. K., H. T. Odum, T. R. Hellier, Jr., and F. H. Berry. 1957. Populations of spotted sunfish and Florida largemouth bass in a constant temperature spring. Trans. Amer. Fish. Soc. 85:120-134.

Carbine, W. F. 1939. Observations on the spawning habits of centrarchid fishes in a deep lake, Oakland County, Michigan. Trans. N. Am. Wildl. Conf. 4:275:287.

Carr, M. H. 1942. The breeding habits, embryology, and larval development of the largemouth black bass in Florida. Proc. New England Zool. Club 20:43-77.

Chastain, G. A. and J. R. Snow. 1966. Nylon mats as spawning sites for largemouth bass, Micropterus salmoides (Lacepede). Proc. Annual Conf. S.E. Assoc. Game Fish Comm. 19:405-408.

Childers, W. F. 1967. Hybridization of four species of sunfishes (Centrarchidae). Ill. Nat. Hist. Surv. Bull. 29(3):159-214.

Culler, C. F. 1938. Notes on warm-water fish culture. Prog. Fish-Cult. 36:19-24.

Davis, H. S. 1930. Some principles of bass culture. Trans. Am. Fish Soc. 60:48-52.

Davis, H. S. 1953. Culture and disease of game fishes. University of California Press, Los Angeles. 322 p.

Davis, H. S. and A. H. Wiebe. 1930. Experiments in the culture of the black bass and other pondfish. U.S. Bur. Fish. Doc. No. 1085. 27 p.

Flickinger, S. A., R. J. Anderson, S. J. Puttmann. 1975. Intensive culture of smallmouth bass. Pages 373-379 in H. Clepper, ed. Black Bass Biology and Management. Sport Fishing Inst., Washington, D.C.

Flickinger, S. A. and D. L. Langlois. 1976. Feeding artificial diets to smallmouth and largemouth bass. Presented at the Am. Fish. Soc. Natl. Fish Cult. Workshop. Springfield, MO. 12 p.

Harper, D. C. 1938. Crappie and calico bass culture in Texas. Prog. Fish-Cult. 38:12-14.

Hayford, C. O. 1927. Artificial production of food for young bass. Trans. Am. Fish. Soc. 57:143-149.

Higgenbotham, B. J., R. L. Noble, and A. Rudd. n.d. Culture techniques of forage species commonly utilized in Texas waters. mimeo.

Hublou, W. F. 1963. Oregon pellets. Prog. Fish-Cult. 25(4):175-180.

Huet, M. 1970. Textbook of fish culture. Fishing News (Books) Ltd. London. 436 p.

Inslee, T. D. 1975. Increased production of smallmouth bass fry. Pages 357-361 in H. Clepper ed. Black Bass Biology and Management. Sport Fishing Inst. Washington, D.C.

Jackson, U. T. 1979. Controlled spawning of largemouth bass. Prog. Fish-Cult. 41(2):90-95.

Johnston, P. M. 1953. The embryonic development of the swim-bladder of the largemouth black bass, Micropterus salmoides (Lacepede). J. Morphol. 93(1):218-226.

Jurgens, K. C. and W. H. Brown. 1954. Chilling the eggs of the largemouth bass. Prog. Fish-Cult. 16(4):172-175.

Kramer, R. H. and L. L. Smith, Jr. 1962. Formation of year classes in largemouth bass. Trans. Am. Fish. Soc. 91(1):29-41.

Langlois, T. H. 1931. The problem of the efficient management of hatcheries used in the production of pond fishes. Trans. Am. Fish. Soc. 61:106-115.

Lawrence, J. M. 1958. Estimated size of various forage fishes largemouth bass can swallow. Proc. Annual Conf. S.E. Assoc. Game Fish Comm. 11:220-225.

Leary, J. L. 1907. Description of the San Marcos Station with some of the methods of propagation in use at the station. Trans. Am. Fish. Soc. 37:75-81.

Leary, J. L. 1909. Propagation of crappie and catfish. Trans. Am. Fish. Soc. 38:143-148.

Lewis, W. M. and R. Heidinger. 1971. Supplemental feeding of hybrid sunfish populations. Trans. Am. Fish. Soc. 100(4):619-623.

Lewis, W. M. and R. C. Heidinger. 1978. Use of hybrid sunfishes in the management of small impoundments. Pages 104-108 in G. D. Novinger and J. G. Dillard eds. New Approaches to the Management of Small Impoundments. North Central Div. Am. Fish. Soc. Spec. Publ. No. 5.

Lydell, Dwight. 1906. The bass at the Mill Creek Station. Trans. Am. Fish. Soc. 35:171-181.

Manual of Fish Culture. 1900. Revised ed. U.S. Fish Comm. Washington: Govt Printing Office. 340 p.

McComish, T. S. 1968. Sexual differentiation of bluegills by the urogenital opening. Prog. Fish-Cult. 30(1):28.

McCraren, J. P. 1974. Hatchery production of advanced largemouth bass fingerlings. Proc. Annual Conf. West. Assoc. Game Fish Comm. (54):260-270.

McCraren, J. P. 1975. Feeding young bass. Farm Pond Harvest 9(3):10-12.

Meehan, O. L. 1939. A method for the production of largemouth bass on natural food in fertilized ponds. Prog. Fish-Cult. 47:1-19.

Millard, J. L. 1978. Intensive culture of largemouth bass. Comm. Fish Farmer 4(5):16-18.

Miller, K. D. and R. H. Kramer. 1971. Spawning and early life history of largemouth bass, *Micropterus salmoides* (Lacepede), in Lake Powell. Pages 73-83 in G. E. Hall, ed. Reservoir fisheries and limnology. Am. Fish. Soc. Spec. Publ. 8.

Ming, A. 1971. A review of the literature on crappies in small impoundments. Mo. Dept. Cons., Div. Fish., Fish. Research Sect. Proj. No., F-1-R-20. Study No. I-15, Job No. 1.

Moorman, R. B. 1957. Reproduction and growth of fishes in Marion Co., Iowa farm ponds. Iowa St. Coll. J. Sci. 32(1):71-88.

Mraz, D. and E. L. Cooper. 1957. Reproduction of carp, largemouth bass, bluegill, and black crappies in small rearing ponds. J. Wildl. Mgmt. 21(2):127-133.

Murphy, M. J. 1980. Acceptability of various diets to centrarchid bass fry. M.S. thesis. Colorado State University, Fort Collins. 28 p.

Nagle, T. 1976. Rearing largemouth bass yearlings on artificial diets. Ohio Dept. Nat. Resour. Div. Wildl. In-service Note 335:6.

Nelson, J. T. and R. G. Bowker. 1974. Rearing pellet fed largemouth bass in a raceway. Prog. Fish-Cult. 36(2):108-110.

Parker, W. D. 1971. Preliminary studies on sexing adult largemouth by means of an external characteristic. Prog. Fish-Cult. 33(2):55-56.

Petit, G. D., III. 1973. Stake beds as crappie concentrators. Proc. Annual Conf. S.E. Assoc. Game Fish Comm. 26:401-406.

Siefert, R. E. 1968. Reproductive behavior, incubation, and mortality of eggs, and postlarval food selection in the white crappie. Trans. Am. Fish Soc. 97(3):252-259.

Smeltzer, J. F. 1981. Culture, handling, and feeding techniques for black crappie fingerlings. M.S. thesis, Colorado State University, Fort Collins. 58 p.

Smith, S. L., J. E. Crumpton, H. E. Evans, and C. M. Rush. 1977. Use of human chorionic gonadatropin (HCG) to promote gametic production in male and female largemouth bass. Annual Report, Largemouth bass investigations. Federal Aid in Fish Restoration, Dingell-Johnson Proj. F-24:17 p.

Snow, J. R. 1960. An exploratory attempt to rear largemouth black bass fingerlings in a controlled environment. Proc. Annual Conf. S.E. Assoc. Game Fish. Comm. 14:253-257.

Snow, J. R. 1965. Results of further experiments on rearing largemouth bass fingerlings under controlled conditions. Proc. Annual Conf. S.E. Assoc. Game Fish Comm. 17:303-313.

Snow, J. R. 1968a. The Oregon Moist Pellet as a diet for largemouth bass. Prog. Fish-Cult. 30(4):235.

Snow, J. R. 1968b. Production of six to eight inch largemouth bass for special purposes. Prog. Fish-Cult. 30(3):144-152.

Snow, J. R. 1969. Some progress in the controlled culture of the largemouth bass, *Micropterus salmoides* (Lacepede). Proc. Annual Conf. S.E. Assoc. Game Fish Comm. 22:380-387.

Snow, J. R. 1970. Culture of largemouth bass. *In* Report of the 1970 Workshop on Fish Feed Technology and Nutrition. Resource Publ. U.S. Bureau Sport Fish. and Wildlife. 102:86-102.

Snow, J. R. 1971a. Fecundity of largemouth bass, Micropterus salmoides (Lacepede), receiving artificial food. Proc. Annual Conf. S.E. Assoc. Game Fish Comm. 24:550-559.

Snow, J. R. 1971b. Culture of large bass fingerlings on artificial food. Paper presented at the Tennessee Fish Farmers Conf. Mimeo. 14 p.

Snow, J. R. 1973. Controlled culture of largemouth bass fry. Proc. Annual Conf. S.E. Assoc. Game Fish Comm. 26:392-398.

Snow, J. R. 1975. Hatchery propagation of the black basses. Pages 344-356 in H. Clepper ed. Black Bass Biology and Management. Sport Fishery Inst. Washington, D.C.

Snow, J. R., R. O. Jones, and W. A. Rogers. 1964. Training Manual of Warmwater Fish Culture. Third Ed. Bureau of Sport Fisheries and Wildlife. 460 p.

Snow, J. R. and J. I. Maxwell. 1970. Oregon Moist Pellet as a production ration of largemouth bass. Prog. Fish-Cult. 32(2):101-102.

Snow, J. R. and C. F. Wright. 1976. Rearing largemouth bass fingerlings in cages. Proc. Annual Conf. S.E. Assoc. Game Fish Comm. 29:74-81.

Stevens, R. E. 1970. Hormonal relationships affecting maturation and ovulation in largemouth bass, Micropterus salmoides (Lacepede). Ph.D. thesis. North Carolina State Univ., Aurora. 95 p.

Stranahan, J. J. 1906. Assorting brood black bass to prevent cannibalism. Trans. Am. Fish. Soc. 35:183-186.

Surber, E. W. 1948. Chemical control agents and their effects on fish. Prog. Fish-Cult. 10:125-131.

Swingle, H. S. 1945. Improvement of fishing in old ponds. Trans. North Am. Wildl. Conf. 10:299-308.

Swingle, H. S. 1950. Relationships and dynamics of balanced and unbalanced fish populations. Bull. 274 Ala. Polytech. Inst. Agric. Exp. Stn. 73 p.

Swingle, H. S. 1956. Appraisal of methods of fish population studies. Patt 4: Determination of balance in farm fish ponds. Trans. North Am. Wildl. Conf. 21:298-322.

Swingle, H. S. and E. V. Smith. 1938. Management of farm fish ponds. Agric. Exp. Stn. Ala. Polytech. Inst., Auburn, Alabama. Mimeo. 6 p.

Swingle, H. S. and E. V. Smith. 1942. The management of farm fish ponds. Bull. 254. Ala. Agric. Exp. Stn., Auburn, Alabama. 23 p.

Swingle, H. S. and E. V. Smith. 1943. Factors affecting the reproduction of bluegill bream and largemouth black bass in ponds. Circ. 87. Ala. Polytech. Inst. Exp. Stn. 8 p.